Vowel acoustics and tongue postures across different head angles

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Recent research on body and head positions show that different postural changes may induce different degrees of changes on acoustic speech signals (Flory, 2015; Vorperian et al., 2015). Compared to pitch, formants were less susceptible to different postural changes. While the preservation of formant profiles across different postures is suitably accounted for by the two-tube model (Stevens, 1998; Fant, 2006) and perturbation theory (Chiba & Kajiyama, 1941), it remains unclear whether the preservation of formants is resulted from the accommodation of tongue postures. In particular, whether the angle between the front and back tubes has any impact on the vowel acoustics, including pitch and formants, is not examined. Furthermore, it remains unclear whether the tongue would accommodate the changes in head angles while maintaining target acoustics. Previous studies summarized three major patterns of tongue movements: pivotal rotation, arching/de-arching, and shift (Iskarous, 2005; Kim et al., 2019). Considering a direct relationship between vowel acoustics and articulatory tongue postures, postural accommodation of the tongue is anticipated in compensation for different head angles (i.e., the angles between the two tubes). The present study examines the vowel acoustics and the articulatory maneuvers of the tongue across different head angles.

Native speakers of Taiwan Mandarin were recruited for a vowel production experiment, in which ultrasound image technique was employed. The experiment involves repetitive [a, i, u] production at eight different head angles: chin-down (-15°, -10°), horizontal (0°), and chin-up (10°, 15°, 45°, 60°, and 90°). At each angle, participants were instructed to produce the designated vowels with ten consecutive tokens (3 vowels × 8 angles × 10 repetitions = 240 trials per participant). The speaking rate was paced at around 1 word/sec. Produced vowels were first labelled in Praat. Pitch and formant trajectory profiles of the vowel segments were obtained using Praat scripts. Estimated non-linear pitch trajectories were fitted through Generalized Additive Mixed Models (GAMMs; Wieling, 2018). Still images of tongue postures were captured from the midpoint of the labelled vowel interval, using a customized MatLab script. Tongue postures were then traced through a MatLab-based Livewire algorithm for tongue images. The tongue traces were converted into polar coordinates and fitted through smoothing spline analysis of variance (SS ANOVA) with 95% confidence interval (Davidson, 2006).

A number of findings are drawn from the preliminary results (4 participants). First, head angle changes do not yield uniform pitch alternations across all vowels; pitch level for [a] appears to be more resistant from angle changes than the other two vowels (Fig. 1 & 2). Second, positive or negative head angles do not necessarily induce pitch elevation or lowering; not all positive head angles (i.e., chin-up) induce pitch elevation and not all negative head angles (i.e., chin-down) yield pitch lowering. Third, pitch alteration across different head angles may interact with vowels' intrinsic F0. Fourth, formant (F1 and F2) distributions were largely unaffected by head angles. Finally, the tongue movement patterns appear to be vowel-dependent: more arching in [a], pivotal rotation in [i], and a mixture of shift and pivotal rotation for [u] (Fig. 3).

The results show that different head angles may result in pitch fluctuation but less much so in formant performances. These acoustic properties are best accounted for by physiological mechanisms: head-rising (chin-up position) raises the larynx, which consequently affects pitch level; formants were preserved through the accommodation of the tongue postures. The results also suggest that different head angles do not impose uniform effects on the vowel acoustics as the variations of pitch and the patterns of tongue accommodation are both vowel-dependent.

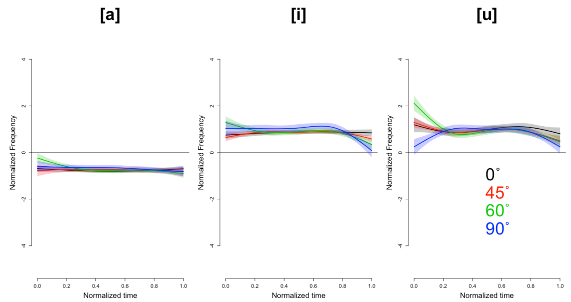

Figure 1 Pitch at horizontal and chin-up angles

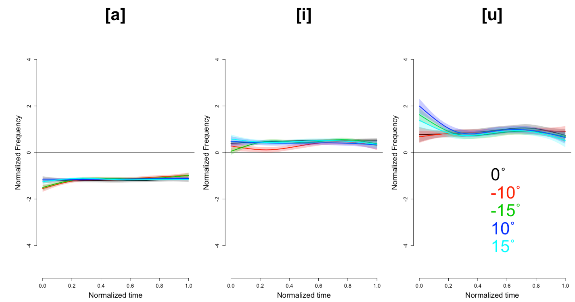

Figure 2 Pitch at horizontal and chin-down angles

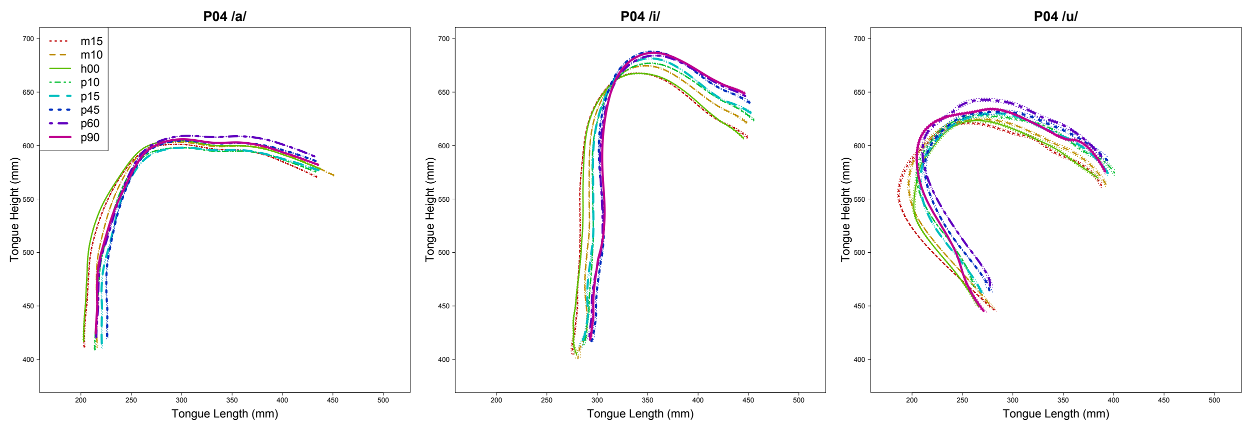

Figure 3 SS ANOVA results of tongue postures across three vowel contexts (one representative participant)

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